USING INTEGRATED SERVICES DIGITAL NETWORK TECHNOLOGY AS THE BASIS FOR THE ROYAL AUSTRALIAN AIR FORCE INFORMATION SYSTEMS GOAL ARCHITECTURE

THESIS

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Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Information Resource Management

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December 1989

Approved for public release; distribution unlimited

<u>Preface</u>

The purpose of this study was to make an assessment of the suitability of Integrated Services Digital Network (ISDN) technology for meeting the Royal Australian Air Force (RAAF) Information Systems (IS) goal architecture. The report contains some technical information on network protocols, so if you do not have a good understanding of networking you may wish to consult the network primer at Appendix A.

The lack of specific data on future network load requirements forced me to resort to a concept of a standard work unit (SWU) to gain some appreciation of the transfer capability of the basic ISDN channel. This reduced the strength of the conclusions that could be drawn from the analysis of network performance.

In performing the analysis of requirements and investigating alternative solutions I received help from a number of people. I would like to thank my thesis advisor, Capt Bruce L. George, Ph.D., for his support and guidance in completing this task. He was particularly helpful in recommending the use of computer simulation to support the findings. SQNLDR Bill Ely from DIS-AF kept me informed on the changing computing environment in the RAAF and I would like to thank him for that. I also wish to thank Capt David M. Brabender from the USAF Model Base Program for sharing ideas of base communications requirements during my visit to Mather AFB, CA. Finally, I would like to thank my wife Carol for her patience and understanding during this epic event.

Richard M. Halley

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<u>List of Symbols</u>

ADP	Automatic Data Processing
ADPCM	Adaptive Differential PCM
AIX	IBM's version of Unix
ANZ	Australia/New Zealand
ATM	Asynchronous Transfer Mode (Used in B-ISDN)
B	Refers to ISDN 64 kbps Bearer (data) channel
BRI	ISDN Basic Rate Interface (2B + D)
B-ISDN	Broadband ISDN
C^3I	Command, Control, Communications and Intelligence
CC	Computer Centre
CCITT	Consultative Committee of International Telephony and Telegraph
CL	Connectionless (OSI network service)
CO	Connection Oriented (OSI network service)
CRC	Cyclic Redundancy Check
CSMA/CD	Carrier Sense Multiple Access/Collision Detection (eg Ethernet)
D	Refers to ISDN 16 kbps (BRI) or 64 kbps (PRI) signalling channel
DA	Data Administrator
DBA	Database Administrator
DBMS	Database Management System
DESINE	Defence EDP Systems Integrated Network Environment
DISCON	Defence Integrated Secure Communications Network
DIS-AF	Directorate of Information Systems - Air Force
DLCI	Data Link Control Identifier (ISDN)
DSS	Decision Support System
DS-1	US 1.544 Mbps digital trunk
EDP	Electronic Data Processing
FCS	Frame Check Sequence (based on CRC to detect errors in a frame)
FIPS	Federal Information Processing Standard (US)
FTAM	File Transfer and Access Method (OSI standard)
GOSIP	Government OSI Profile (US, UK, or Australia)
H0	ISDN 384 kbps data channel
H11	ISDN 1.536 Mbps data channel (North America)
H12	ISDN 1.920 Mbps data channel (Europe and Australia)
HDLC	High-level Data Link Control (Basis of LAPB and LAPD)
IBM	International Business Machines
IEEE 802.5	IEEE standard for Token Ring LAN
IEEE 802.3	IEEE standard for CSMA/CD LAN
IEEE	Institute of Electrical and Electronic Engineers
IRM	Information Resource Management
IS	Information Systems
ISDN	Integrated Services Digital Network
ISO	International Standards Organization
kbps	Kilobits per second
kHz	Kilohertz per second
LAN	Local Area Network
LAPB	Link Access Protocol B (data link protocol for X.25)
LAPD	Link Access Protocol D (data link protocol for ISDN)
LITA	Local Information Transfer Architecture
LLID	Logical Link Identifier
Mbps	Megabits per second

MIS	Management Information System
MLPP	Multi-level Precedence and Preemption
NATO	North Atlantic Treaty Organization
OA	Office Automation
OSF	Open Software Foundation
OSI	Open Systems Interconnection
PC	Personal Computer
PCM	Pulse Code Modulation
PLP	Packet Level Protocol (X.25)
POSIX	Portable Operating System for Computer Environments
PRI	ISDN Primary Rate Interface (23B (North America) or 30B (Europe and Australia) + D)
PSDN	Packet Switched Data Network
Q.931	ISDN Layer 3 signalling standard
RAAF	Royal Australian Air Force
RFT	Request for Tender
RODNET	RAAF On-base Data Network
RS-232	A popular serial interface physical layer protocol
SAPI	Service Access Point Identifier (ISDN)
SNA	System Network Architecture
SQL	Structured Query Language
SWU	Standard Work Unit
TA	Terminal Adapter
TEI	Terminal Endpoint Identifier (ISDN)
TLI	Transport Layer Interface (defined by AT&T)
TP	Transport Protocol
TP0	Simple TP Class 0 (relies on a reliable network service)
TP2	Similar to TP0 except has multiplexing capability
TP4	Full-blown TP that assumes an unreliable network service
UI	Unix International
UK	United Kingdom
US/USA	United States of America
V.110	ISDN rate adaption standard (bit multiplexing)
V.120	ISDN rate adaption standard (LAPD multiplexing)
WAN	Wide Area Network
WG	Work Group
X.21	Physical layer for X.25 (requires digital network)
X.21bis	Alternative physical layer for X.25 (similar to RS-232)
X.25	CCITT standard for PSDN
X.31	X.25 as adapted for ISDN
X.75	CCITT standard for interconnecting X.25 networks

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Abstract

thesis

The purpose of this ~~study~~ was to define an information systems goal architecture for the Royal Australian Air Force that uses Integrated Services Digital Network (ISDN) as the basic network structure. To do this required gathering information from previous studies on architecture requirements and present related projects. Important requirements were identified as the ability to exchange data between the various systems, the requirement to protect classified data and the requirement to support deployed RAAF operations.

An important Australian Defence project is the Defence EDP Systems Integrated Network Environment (DESINE) that is intended to achieve interoperability among the various information systems. DESINE details are not firm, but early indications are that proprietary IBM network protocols will be used with a strong emphasis on mainframe computing. This concept is contrary to the current industry trends where the use of smaller microcomputer based systems that use open systems architectures is advocated. The architecture presented in this report is offered as an alternative to DESINE.

Analysis of the options for using ISDN technology indicated that the concept of frame relay is ideally suited to the RAAF requirements. Frame relay is a form of packet switching, within an ISDN, where high throughput and low delay are achieved by reducing the processing required per packet. A migration path using conventional X.25 packet switching is proposed.

The proposed architecture distributes processing power to user locations to reduce the network traffic. This setup was simulated using the CACI COMNET II.5 program and used a surrogate load measure based on a standard work unit. This was necessary because of the unavailability of projected network load data. The results indicated that with distributed processing ISDN can meet all the requirements of the RAAF goal architecture.

USING INTEGRATED SERVICES DIGITAL NETWORK TECHNOLOGY
AS THE BASIS FOR THE ROYAL AUSTRALIAN AIR FORCE
INFORMATION SYSTEMS GOAL ARCHITECTURE

I. Introduction

General Issue

In October 1986, the Royal Australian Air Force (RAAF) Computing Systems Policy Committee endorsed a paper titled "RAAF ADP Development Plan." This plan advocates the development of information systems (IS) along the vertical lines of the four functional elements of operations, administration, supply, and maintenance. A subsequent draft paper titled "A Development Framework for RAAF Information Systems" stressed the importance of a unifying total system concept, the transfer of data between the functional element systems, and the requirement to protect classified data (33). This second paper is discussed in Chapter II. There are two defence-wide projects that are designed to simplify the integration of IS within the three Services and Defence Central and to provide interoperability between the various agencies.

The first project is the Defence Integrated Secure Communications Network (DISCON), which will provide a strategic, operational and day-to-day communications capability. Initial services, which are just starting to become available, include secure voice, facsimile, message switching and dedicated data circuits. The network is being expanded to include classified and unclassified data packet switching services. This expansion will provide the wide area network (WAN) capability to

allow the transfer of data between IS at the various defence establishments.

The other major project is also concerned with providing a standardized networking capability. The Defence EDP Systems Integrated Network Environment (DESINE) will allow the inter-networking of various computer systems in a consistent way. The concept of DESINE is to allow the decentralization on IS by providing a standard network architecture for the interoperation of distributed computer systems. The DESINE standards are to be used for all defence IS computing requirements, unless an exemption is obtained (10).

The DESINE contract has been awarded to IBM Australia Ltd and is effective from 1989 to 1994. Because of the recency of this award there is still some confusion as to what products will be made available under DESINE. Early indications are that IBM's proprietary System Network Architecture (SNA) will be used with an emphasis on mainframe based solutions (19). At least four different levels of computing will be provided, ranging from the IBM 3090 mainframe to an IBM PC, with each level using a different operating system. Many RAAF IS project managers have found it difficult to match a DESINE based solution to their user requirements (14).

In defining the requirements for DESINE, the IS policy makers recognized that there may be circumstances where DESINE based solutions may not be appropriate. This may include embedded systems, specialist systems that have security concerns, urgent operational requirements, and unsuitable contract solutions. Solutions could be unsuitable because of function, time required to implement, or project costs where project costs includes all aspects of the introduction of the system (11:3).

The use of DISCON to provide the WAN capability will be an important component of the IS development strategy, but equally important is the development of a unifying total system concept that meets the management and operational needs of the RAAF. IS in the RAAF involve more that just support for the four functional elements. Future systems will include office automation (OA), management information systems (MIS) and decision support systems (DSS) to support the activities of middle and upper level management. These MIS and DSS will use the corporate data provided by the functional systems, and may cross functional boundaries. An example of this would be mission planning that requires weapon and POL availability, aircraft and aircrew availability, and accommodation requirements at another base.

The area that is concerned with the management of these decision aiding tools, and the information they process, is referred to as information resource management (IRM). IRM has the concept that information is an organizational resource and requires top level attention to ensure it is managed correctly. The IRM function is involved with traditional data processing applications, telecommunciations and OA and is an attempt to provide a coordinated approach to the management of IS (8:632-633).

Specific Problem

The concept of operations of the RAAF requires the support for deployed operations that may be from non-operational RAAF bases, unmanned RAAF bases, and possibly civilian airfields. The IS that are developed to support the four functional elements must take these deployed operations into account. This research will determine a RAAF IS goal architecture based on Integrated Services Digital Network (ISDN)

technology, that uses DISCON to provide the WAN component, and although not specifically based on DESINE products, will meet the DESINE goals.

Definition of ISDN. Integrated Services Digital Network (ISDN) is defined by the Consultative Committee of International Telephony and Telegraph (CCITT) as an access method where a small number of standardized interfaces are used to provide a single access-point to an end-to-end digital network providing voice, video, circuit switched data and packet switched data services (38).

Research Objectives

The following steps are required to determine the IS goal architecture:

1. identify RAAF IS requirements sufficient to allow network service and capacity planning;
2. determine any computer industry trends that are applicable to RAAF IS development;
3. identify the goals of the DESINE project;
4. identify DISCON interfacing specifications and associated network protocols;
5. determine how ISDN technology can be used to facilitate base level communications;
6. design the goal architecture based on the information obtained above; and
7. evaluate the goal architecture using simulation to assess network performance.

Scope of the Research

There are several existing IS in use in the RAAF today and each of the four functional elements has identified requirements for new or replacement IS in the near future. This research will not look at any requirements of the existing functional systems, but instead will define an architecture for the integration of the new systems. Additionally, the research will concentrate on establishing a base level architecture. The RAAF goal architecture would consist of a hierarchy of appropriately sized network configurations at all bases, depots, headquarters and Air Force Office.

Background

Chapter II provides some detailed background on topics that are relevant to the selection of the goal architecture. First a more detailed look at the paper titled "A Development Framework for RAAF Information Systems" gives some guidance on the problems that must be solved. Current RAAF IS policy and any existing projects that may relate to this research are discussed and an assessment made of the level of maturity of the development of IS in the RAAF. Then the ISDN concept is explained in general terms and more specifically how the military can benefit from ISDN technology. Finally a look at how the US Military is planning to use ISDN technology for local information transfer and to provide world-wide interoperability.

II. Background

A Development Framework for RAAF Information Systems

The concept for the development of information systems in the RAAF is along the vertical lines of the four functional areas of operations, administration, supply and maintenance. A hierarchy of automatic data processing (ADP) sites is to be established at RAAF bases, supply and maintenance depots, Air Headquarters, Support Command, and Air Force Office. Components of the information systems for each functional element would be housed in these ADP sites. At each node in the hierarchy some form of local area network (LAN) would be used to provide user access to the information systems (33:1-2).

Support for Deployments. At the base level the functional elements are overlaid by the particular operational role of that base. While an operational role is concentrated at a 'home' base, the concept of operations requires support for deployed forces at any other operational or non-operational base. The development of information systems must take these deployed operations into account (33:2). Two other important considerations in the development of information systems are interoperability and security.

Interoperability. Each functional element will have private data and data that is required to be shared with the other elements. Interoperability is concerned with the management and control of this shared data. Having defined inter-networking standards will greatly assist data interoperability but some method for standardized data interchange must be provided (33:4).

Security. The information that will be stored on general purpose information systems can be divided into two security levels;

Unclassified-Restricted and Confidential-Secret. Additionally, data may be classified on a need-to-know basis. The development framework proposes the installation of separate LANs to service users at the two security levels. Operations staff would primarily operate on the higher level LAN, while the other elements would use the lower level system. A one-way link from the lower level to the higher level system must be provided. Additionally, some information from the Confidential-Secret level must be made available to selected users outside of operations that have the need-to-know and appropriate security clearances (33:6).

RAAF IS Policy and Existing Projects

To meet the demand for general computing services the RAAF Computing Services Policy Committee endorsed the policy in October 1986 that stated, wherever possible, user computing support requirements should be provided by Unix based multi-user minicomputers. This decision resulted in the acquisition of about 80 small to medium size multi-user computers for use in all functional areas. These systems are using the Uniplex II Plus integrated office system and the Informix database management system (7:13).

To continue the work started with the paper discussing the development framework for RAAF IS, a project called RAAF On-base Data Communications Network (RODNET) was initiated to progress the development of a high capacity LAN infrastructure. The current status of RODNET is unknown, but believed to be at a very early stage of requirements definition. The goals of RODNET and of this research are much the same and this should at least provide two different approaches to solving base-level communications requirements.

RAAF Information Systems Maturity

The Nolan six stage model is a useful conceptual tool to help understand the level of maturity that information systems have reached in an organization. The model consists of six necessary stages of growth toward maturity. The six stages are initiation, uncontrolled expansion, control and planning, integration of applications, data administration activity, and maturity where applications are complete and match the organizational objectives (8:450-453).

The introduction of the Unix based general purpose computing systems provided the first wide-spread use of computers in the RAAF outside the data processing areas. Because of the difficulty in computer acquisition, many agencies applied the 'back door' approach to acquire computing support, mainly in the form of PCs. This led to a non-standard approach to solving IS problems. In 1987, Air Force Office became aware that the management of RAAF computing resources and future requirements was a formidable task. To tackle this task, the Directorate of Information Systems - Air Force (DIS-AF) was formed to replace the directorate previously responsible for such matters. Among other responsibilities, DIS-AF would determine and promulgate policy and procedures for the development of computing within the RAAF (7:13).

The RAAF has recognized, but not yet solved, the problems associated with the introduction and management of IS. This would seem to place the RAAF at the Nolan control and planning phase.

The ISDN Concept

The Need for Integration. A telephone network consists of a large number of telephones and a series of interconnected switching centers or exchanges. Early networks used only analog techniques where voice information is transmitted by modulating voltage signals on the telephone line. By the 1970s, the telephone network providers had realized the reliability and economic advantages of using digital switching of information between the exchanges (15:332). To utilize digital switching a voice signal must be converted to a digital format where a pattern of binary zeros and ones is used to represent the voice pattern. The widespread use of digital computers in the business world has led to the development of dedicated data networks. These data networks are usually operated by the telephone companies (15:333). The phased development of the telephone and data networks in different countries has led to minor differences in implementation standards (32:835). These differences affect the ability to provide efficient, world-wide communications. If the voice and data networks can be integrated into a combined digital network there would be an improvement in network services and significant savings in maintenance costs (15:333). Integrated Services Digital Network (ISDN) is the only technology being considered to provide this integration (32:833).

ISDN Interface Standards. The ISDN standards specify separate data and network signalling channels. The data (B) channels are 64 kbps (kilo, meaning thousands, bits per second) and an ISDN interface can have from two to 30 such channels. A Basic Rate Interface (BRI) has two B channels and in Australia the Primary Rate Interface (PRI) has 30 B channels. Each interface has a separate (D) channel for network signalling and control (30:762). All channels are multiplexed, or

combined, so they can be transmitted over the existing telephone wiring between the exchange and the ISDN access point. This provides access to data as well as voice services from any telephone connection in an ISDN (30:762).

Existing Data Networks. An implementation plan for an ISDN must allow for integration of existing terminal equipment and data networks. ISDN adapters will be available for most of the existing hardware and the standards provide for initial access to existing data networks from the ISDN interface (32:837). The amount of money invested in these data networks will to a large extent determine when all services are converted to ISDN (15:336). The most common type of data network is the X.25 packet switching network and ISDN standards provide two ways to interface to these networks. The first is to use the unused capacity of the D signalling channel to transfer packet data. The second method is to use the signalling channel to establish a circuit switched connection to a packet switching node over a B data channel (38:277).

Developments in Video Transmission. To transmit a full motion video signal in a digital format requires about 80 Mbps of bandwidth. Until B-ISDN is widely available, this high bandwidth requirement will limit the distribution of normal TV video using normal ISDN capabilities. However, one area where video is becoming increasingly important is in teleconferencing. Considerable bandwidth can be saved by only transmitting the changes necessary to reconstruct the video picture, instead of the whole video frame many times per second. Good quality video, suitable for teleconferencing, can be transmitted in as little as 384 kbps. With reductions in quality, for security surveilance for example, the bandwidth can be reduced even further. The

decision to use 384 kbps was made because that was a standard channel available in ISDN (21:30).

Future ISDN Developments

Enhanced Packet-mode Techniques. Most existing data networks use a packet switching technique to maximize network utilization. The network switching nodes divides the data into small packets for routing through the network. More efficient packet-mode techniques are being planned for ISDN and B-ISDN that will allow the complete replacement of the existing networks (16:345). Using packet switching within a single B data channel would allow up to 16 terminals to effectively share the same ISDN interface (30:763). Enhanced packet-mode techniques will also be the basis of LAN inter-connection using ISDN (6).

Broadband ISDN. To satisfy much higher data transfer requirements, the CCITT is processing recommendations for the specification of a Broadband ISDN (B-ISDN). This new technology will use fiber optics and be capable of data rates of 150 mbps (million bps) (16:343). This will allow the distribution of high quality, full bandwidth video. The price of B-ISDN is likely to be similar to cable TV and this widespread availability of cheap, high capacity data services should be useful to the military (35:778).

Military Use of ISDN

ISDN techniques provide solutions to most of the communications problems that the military have faced in the past. These include poor utilization of data circuits, incompatibility between various hardware vendors, and slow provisioning times (29:50.5.2). Most industrialized countries, including NATO members and other allies, are committed to

implementing ISDN (35:778). A 64 kbps channel can provide high quality voice or be used to transport computer or other data. As many existing military users are transmitting data at 9.6 kbps or less, a lot of military communications requirements can be met by the standard 64 kbps B data channel. If required, the data channels can be combined to give higher transfer rates (32:833). Soon the most common telecommunications interface to be found around the world will be an ISDN connection and the military should not miss out on this opportunity for global connectivity (32:835).

The common network signalling and control channel provides much of the flexibility in the ISDN. As well as providing normal call set-up and monitoring, like identifying a pending caller when phone is in use, specific user-to-user signalling protocols can be developed. These additions are allowed for in the ISDN specifications (32:835). Commercial ISDN implementations would meet most of the military's requirements, but areas of access control, preemption, network management, and encryption must be further examined.

Access Control. ISDN calling procedures can improve access control by passing the caller's number when a call is established. Additional information such as user-ID can also be passed. This signalling protocol can be used to grant or deny access to any telephone number and user-ID combination (30:766). The standards committees have discussed increasing the access control capability of ISDN but more detailed study is still required (32:836). According to Mercer and Edwards the onus is on the military to identify any special requirements to ensure they can be implemented in a consistent manner (29:50.5.1).

Preemption Capability. Military communications must ensure that essential C^3I and other high precedence traffic is not blocked in a busy

network. Existing military networks provide a multi-level precedence and preemption (MLPP) capability to prevent blocking, and recently the Defense Communications Agency submitted MLPP requirements to the standards committees (32:836). The military will have to pay for this capability to be built into military ISDN switches as preemption on public networks is not permitted (24:722).

Network Management. The flexible common signalling channel in the ISDN interface improves the network management and maintenance capabilities (35:777). The customer has more control over an ISDN and can initiate reconfiguration during periods of degraded operation. The rapid switching capability of an ISDN allows virtual private networks to be established and disbanded on demand within seconds. This improves network availability by allowing the switching exchanges to route traffic around any faulty paths (30:568). This is the type of flexible network management required in a military network (29:50.5.3).

Encryption. The separation of network signalling from data simplifies the use of encryption devices in an ISDN and allows military users to pass encrypted, sensitive data over public networks (35:766). This is possible because the connection is made using the D signalling channel and data passed on the encrypted B channel. Some of the current encryption devices may not be compatible with ISDN and will therefore need replacing (32:837).

US Military ISDN Plans

The US Army, Navy, and Air Force have all included ISDN technology as part of the solution to providing for the local transfer of information in the post-1995 time frame. Each Service has taken a different approach and each will be discussed briefly below.

Army. The Army considers that most users can be serviced by the 2B + D BRI and intends to replace most of its 20,000 LANs with this service. Achieving full ISDN capability will take a long time as only about eight of the 400 total switches are being upgraded to an ISDN capability each year (2:362).

Navy. Of the three Services the Navy tends to rely less on fixed shore-based communications facilities. At the base level the main ISDN switch will be connected to smaller ISDN and non-ISDN switches. The Navy sees ISDN technology as a means of connectivity between LANs rather than a replacement for the LANs themselves (2:366).

Air Force. The Air Force intends to use ISDN to provide world-wide interoperability between its bases (2:366). The Air Force has the most advanced plans for the introduction of ISDN services. The local information transfer architecture (LITA) consists of multiple ISDN switches connected via high-capacity fiber optics. Again most users will be provided with the 2B + D BRI (13:page 3-1).

Comments and Conclusions

The formation of DIS-AF is an important step in progressing the state of RAAF IS towards maturity, although a lot of work lies ahead. The development framework for RAAF information systems has indicated that the three main areas for concern are the support for deployed operations; interoperability between the operations, administration, supply, and maintenance systems; and protecting classified information but still making it available to authorized users. A key component of the goal architecture is the LAN and it appears that ISDN is a suitable candidate.

The conversion of the public telephone networks to an ISDN will result in increased functionality at lower costs. An ISDN is capable of combining all voice and data requirements into one network. The separation of the network signalling from the data provides much of the flexibility of the ISDN. All industrialized nations are planning for ISDN, and this is the only technology being considered for the future.

While many military needs could be met by standard commercial ISDN implementations, there are some unique military requirements that must be factored into the ISDN development process. These requirements are for better access control and network management capabilities, a preemption capability, advanced conferencing facilities and the use of encryption equipment on public networks.

Initial implementations can use existing terminal equipment and X.25 packet switching data networks until they can be cost-effectively replaced. The planned developments of the enhanced packet-mode capability, and of B-ISDN, further support that this is the type of technology that the military should be adopting and encouraging.

In the US, all three Services have included ISDN in their local information transfer architectures. The flexibility of ISDN seems to meet the military's communications requirements using mainly standard commercial implementations. For the same reasons, this is the type of technology that should be considered for the RAAF information systems goal architecture.

III. Methodology

The methodology used to determine the architecture was based on authoritative opinion with simulation used to evaluate the solution. The steps followed to satisfy the research objectives are described below.

Research Objectives Steps

IS Requirements. A letter was sent to DIS-AF requesting information on the types of services and estimated traffic volume for the new functional element information systems and any other known requirements.

Computer Industry Trends. A review of current literature was conducted to establish what current industry trends were applicable to the RAAF IS goal architecture.

DESINE Goals. The same letter to DIS-AF also requested details of the DESINE contract, in particular available computers, operating systems and network protocols.

DISCON Specifications. The Australian Department of Defence - Project Development and Communications Division was contacted to obtain the latest information on DISCON packet switching interfacing requirements.

Options for Using ISDN Technology. A literature review was used to determine the latest ISDN standardization efforts and what future developments are likely. The USAF Local Information Transfer Architecture (LITA) was examined and several aspects of the LITA, that were relevant to the RAAF goal architecture, were discussed with the

Model Base Program staff at Mather AFB, Sacramento CA, during a four day visit in June 1989.

Design Architecture. Using the information derived from above, and considering the requirements for cross-domain access to corporate information, the security aspects, and the support necessary for deployments, a goal architecture was defined.

Evaluate Architecture. The goal architecture was simulated using the CACI COMNET II.5 communications simulation package to determine the throughput and delay parameters of the proposed solution.

IV. Findings

IS Requirements

The four functional elements are at various stages in defining the requirements for specific IS. A recent major reorganization of Air Force Office, and much debate over the virtues of centralized verses distributed database storage, has made it nearly impossible to define IS requirements sufficient to allow a network architecture to be defined. An assumption has been made that user terminals will range from relatively 'dumb' devices for transaction processing, to high performance workstations for command and control or DSS requirements. Another assumption is that there is at least a requirement to have local database storage for some information. As the storage of data is likely to change in the future, as technology allows for truly distributed databases, the goal architecture should be independent of data storage requirements.

The reply received from DIS-AF concerning the new functional element projects had some data associated with network loadings, but unfortunately the information was too general to be useful as input for the computer simulation model (14). Information is required on the type and nature of expected traffic, like the frequency of a particular event and the amount of network data transfer generated by that event. As the information systems for the functional elements are in the early project stages, this type of information is just not available. Because the simulation of the proposed goal architecture is an important part of this research, some other method of providing the network load was required.

The method adopted was to define a standard work unit (SWU) as a number of separate activities completed within a five minute period. The activities consisted of a database query session, where several queries are made separated by simulated user thinking time, and a two-way exchange of messages or files. The details of the SWU are contained in Appendix B.

By defining the SWU it was possible to vary the load applied to the proposed network to see the effect on the throughput and delay performance parameters. These parameters are discussed below in the architecture validation section.

Computer Industry Trends

Network requirements are very much determined by the number and location of computers and terminals/workstations on a typical base. For this reason an assessment of the likely computer configuration was necessary. The following quote provides much insight into the nature of the computer configuration:

> Each of the four fundamental elements will be supported by a discrete Information System that has sub-elements distributed across the WAN. Interoperability between these discrete systems is provided by connectivity through common networks, and by the application of common representation of shared data. The architecture of each functional system will be unique, though resources could be shared if practicable. Processing power will be distributed as necessary to match the demands of local processing requirements, communications requirements, and the economies of central data management. Applications would be distributed as close to the end-user as practicable, with appropriate central configuration management. Local data would be managed at the ADP Centre. (33:10)

Distributed Computing. One of the aims of DESINE is to provide effective vertical and lateral interaction between the distributed computer systems that comprise the functional elements (10:A-1). Activity in the computer industry in general seems to support the

concept of distributed computing. Downsizing is a term that is used to describe designing new systems to operate on departmental minicomputers or networked PCs (17:15). Much of this movement is because of the increased performance and reduced costs of microprocessor based systems. The introduction of widely distributed computer systems requires some changes in the way application programs are development.

Centralized Computing. Earlier concepts of computer architecture consisted of terminals, usually connected to some form of concentrator, that would establish an interactive session with a host computer. Many of these terminals were character based where a character entered on the terminal would be sent to the computer. The computer, or at least a front-end communications processor, would echo the character back to the terminal. If a single character were to be sent using a layered network protocol, where each protocol layer adds more control information, the effective throughput would only be a few percent. Many applications that are based on terminal emulation are not suitable for the distributed environment (27:300).

User Interface Location. One way to avoid the terminal emulation problem is to place the application program, or at least the user interface portion of it, as close to the end-user as possible. This can be achieved by using departmental processors and/or networked workstations/PCs. The application programs can then use the network to gain access to data stored in other computers, either locally or at other network locations. This type of configuration is often referred to as a client-server relationship where the application program is the client and the computer with the database is the server. This establishes a true process-to-process communications link that is capable of making effective use of the network's available bandwith.

Open Systems Computing. The desire to be free of any particular vendor's computing environment, is best summed up in a quote from the developer of the US Government, Federal Information Processing Standards (FIPS):

> For both economic and technological reasons, information systems users can no longer afford the safe haven provided by proprietary solutions. Nor do they seek those safe solutions. Users are now demanding that vendors supply products that meet their requirements for portability and interoperability of software environments and the applications that run in those environments. (26:38)

To meet this level of interoperability requires using vendor independent standards in a number of areas. The four areas that are relevant to this research are OSI networking standards, Portable Operating System for Computer Environments (POSIX), the X-Windows standard, and the Structured Query Language (SQL) for database management and access.

Open Systems Interconnection. Open Systems Interconnection (OSI) defines the network standards necessary to enable vendor independent internetworking of heterogeneous computer systems. OSI is discussed further in Appendix A.

POSIX. POSIX is based on the AT&T Unix System V, and defines standard ways of obtaining operating system services. Unix is the only computer operating system that is capable of being implemented on a wide variety of hardware system and thus is seen as an important element in maintaining vendor independence. Two competing organizations that will play a significant role in the future of Unix are the Open System Foundation (OSF) and Unix International (UI). UI is committed to supporting the future AT&T Unix System V Release 4 and OSF will develop OSF-1 from a version of IBM's AIX, which is itself derived from System V Release 2. There has been a lot of disagreement between the various vendors, but it now appears that both OSF and UI will develop different

Unix implementations, although they both will be based on the POSIX standard (25:141).

Windows Standard. OSF and UI have also defined user interfaces based on the device independent X-Windows standard developed by the Massachusetts Institute of Technology. X-Windows is a windowing standard for bit-mapped displays that is operating system and network protocol independent. The OSF Motif user interface may have more support in the industry (31:53).

Structured Query Language. SQL has become the standard for operation with relational database management systems (DBMS). SQL is the basis for IBM's relational databases and the large DBMS vendors, like Relational Technology Inc. and Oracle Corporation, have also standardized on SQL.

DESINE Goals

DESINE is the outcome of the 1981 Defence Computing Infrastructure Working Party decision to decentralize administrative computing. The scope of DESINE was later expanded to include all non-embedded computer systems suitable for standardization. Decentralization is to be achieved by defining technical standards that would allow the decentralization along functional lines and effective vertical and lateral interaction between differing functions in a distributed computer environment (11:A-1). The benefits of the DESINE contract include:

a. the contracted availability of a range of proven hardware and software products needed to implement a proven network architecture, leading in turn to improved interoperability. This range of products has been evaluated as having the highest overall cost effectiveness available;

b. savings in training and other support costs;

c. increased contingency and backup potential;

d. the contracted availability of acceptable new technology and of products compatible with Defence OSI aims;

e. increased Australian/New Zealand (ANZ) industry participation;

f. a simplified procurement process for the supply of contracted products; and

g. availability of maintenance for 10 years after equipment delivery. (10:1)

DESINE and OSI. Defence is committed to the adoption of the International Standards Organization's (ISO), OSI standards when they become commercially available. The DESINE RFT required a commitment to the implementation of OSI and will implement solutions based on the Australian Government OSI Profile (GOSIP) when it is made an Australian standard. The draft Australian GOSIP Version 1.0 was issued in April 1989 and is based on the UK GOSIP Version 3.0 with changes made to suit Australian requirements (12:iv). If DESINE is implemented using IBM's SNA there are some doubts if compliance with GOSIP will be possible in the near future, if at all. Network experts believe that IBM intends to provide gateway services from SNA to OSI and both architectures will coexist. The use of gateways causes some loss of functionality, for instance reduced speed and compatibility (28:174-175). IBM literature also supports the concept of the co-existence of SNA and OSI for some time into the future (1). The goal architecture will be designed using Australian GOSIP network standards. ISDN standards are not included in the present version of GOSIP, so where such standards are needed, authoritative opinion from current literature was used to assess the likely outcome of standardization activity. Future versions of the Australian GOSIP will include a provision for ISDN (12:1-5).

DISCON Specifications. An aspect that places constraints on the architecture design is the requirement to interface to the DISCON packet switching network for all inter-base communications. Advice received from the Department of Defence - Project Development and Communications Division, was that the packet switching network would at least be using CCITT X.25 (1984) standards, and possibly the 1988 version of the standard (20).

Options for Using ISDN Technology

Basic Building Block. The basic building block of an ISDN is the 64 kbps unrestricted digital channel, which means that the network will pass the bit stream unaltered. This is often referred to as a transparent channel. When the concept of ISDN was first being developed 64 kbps was the bandwith necessary to pass digitized voice. This consisted of an 8 kHz sampling rate with 8 bits in each sample. This form of encoding is called pulse code modulation (PCM). More sophisticated encoding algorithms can reduce the required bandwith. In the early 1980s Adaptive Differential PCM (ADPCM) was introduced that required only 32 kbps to transfer the same quality of voice signal (38:189). Today, 16 kbps is considered adequate for speech encoding, although lower rates are possible (9:231). The rapid development is speech encoding techniques is an example of what the standards committees must contend with. On one hand, trying to define something as complex as ISDN is going to take a long time, meanwhile, technological enhancements can change original assumptions. The whole reason for defining the basic building block as 64 kbps was to be able to pass PCM encoded voice signals. Regardless of the developments in

new voice encoding techniques, the ISDN building block remains as 64 kbps full-duplex channel.

Basic Rate Interface. The basic rate interface (BRI) consists of two independent 64 kbps bearer or B channels and one 16 kbps signalling or D channel. These three channels, that total 144 kbps, are multiplexed over a 192 kbps interface. The additional bandwith is needed for synchronization purposes. The BRI allows for a multi-drop configuration where up to eight physical devices can share the same interface. (38:283).

Primary Rate Interface. The primary rate interface (PRI) structure varies depending on whether the North American or European standard is used. The North American PRI is based on the DS-1 signal structure which is used on the T-1 transmission service at 1.544 Mbps. This consists of 23 B channels and a 64 kbps D channel. The European standard is based on the 2.048 Mbps digital trunk standard. The European PRI consists of 30 B channels and a 64 kbps D channel (38:290). The Australian ISDN standards will be based on the European system.

Other Channel Rates. In addition to PRI access consisting of 23 or 30 B channels, it is possible to combine B channels to provide higher data rate channels. A PRI can provide multiple 384 kbps H0 channels, or all the B channels can be combined giving either a 1.536 Mbps H11 channel (North America) or a 1.920 Mbps H12 channel (Europe). These higher rate channels are suitable for video applications or high speed data channels (38:189-192).

Signalling Channel. Much of the flexibility of ISDN comes from the existence of the separate signalling channel. Unlike the B and H channels that are transparent, as far as the ISDN is concerned, the D channel has a layered structure built upon it.

Link Access Protocol. The first layer consists of a data link protocol called Link Access Protocol D (LAPD). In many ways LAPD is similar to the LAPB used in X.25 Packet Switched Data Network (PSDN). Figure 1 shows the LAPD frame structure.

FLAG	ADDRESS	CONTROL	INFORMATION	FCS	FLAG
8 bits	16 bits	8 or 16 bits	Variable 0 to 260 x 8 bits	16 bits	8 bits

Figure 1. LAPD Frame Structure (38:294)

LAPD is based on the International Standards Organization (ISO) High-level Data Link Control (HDLC) protocol. The flags are used to identify the start and end of a valid frame and consist of a special bit pattern, 01111110. All HDLC type of protocols allow the transparent transfer of user data by a hardware process known as bit stuffing and removal. The concept is to break up sequences of 1s greater than five so the flag patterns can only occur where they should. The reverse procedure is then applied to recover the correct user data. The control field is used to control the operation of the data link. If acknowledged transmissions are being used, which is the normal case, the control field contains frame numbers for error recovery and flow control to prevent a fast transmitter of data from swamping the receiver. The frame check sequence (FCS) is a sophisticated check sum, based on the contents of the frame, which gives a high probability of detecting a corrupt frame. The field that is different from a normal HDLC frame is the address field. LAPD has to deal with two levels of addressing.

First there can be multiple user devices sharing the one interface, so a terminal endpoint identifier (TEI) is used to define the physical device. Within each device there may be several entities using the LAPD service. To differentiate between various entities, a service access point identifier (SAPI) is used. The TEI and the SAPI uniquely identify a LAPD entity, and the corresponding Layer 3 entity, at the ISDN interface (38:295-296).

Network Layer Protocol. The main purpose of LAPD is to pass network layer messages between the ISDN terminal equipment and the network. These network control messages are defined in the Q.931 ISDN standard. Q.931 messages are used in the setup, in-process and termination phases of a call to provide complete control of the connection (38:309). More advanced features, like call forwarding and user groups, can be provided by the Layer 3 messages. Network management features are also implemented by using Q.931. This gives the ability for monitoring network status and invoking fault isolation tests at the ISDN interface (34:6). Q.931 messages have a protocol discriminator at the start of the message to allow multiple Layer 3 entities, identified by different SAPIs, to share the same interface. This feature is used to provide a low volume X.25 data service, as well as Q.931 signalling, in the D channel (38:305).

X.25 Packet Switching Service. The CCITT has defined two methods for interfacing to a X.25 PSDN via an ISDN. The two methods are defined in the X.31 standard and differ in the packet processing location. The first method simply provides a circuit switched B channel from the ISDN to the PSDN and all packet processing in done by the PSDN. The second method is to place a packet handler in the ISDN and to link the packet handler to the PSDN using the X.75 protocol, which is the standard

method of interconnecting separate X.25 networks. The advantages of placing the X.25 packet handler in the ISDN include reduced delay for intra-ISDN traffic and the ability to use either a B channel (using LAPB) or the D channel (using LAPD) (16:346-348).

Multiplexing into the B Channel. For many users who do not require the whole 64 kbps B channel bandwidth, it is desirable to provide a multiplexing capability to allow multiple access to the one B channel. The multiplexing functions are provided by devices called terminal adapters (TA) that allow non-ISDN devices to access the network. Two methods have been standardized to provide B channel multiplexing, the original concept is based on bit level multiplexing and the more recent concept is to multiplex Level 2 frames. Both methods rely on the establishment of a circuit switched B channel which means that all multiplexed data from a channel must have the same destination.

V.110. The standard for bit level multiplexing is called V.110 and allows combinations of 8, 16 or 32 kbps sub-channels. The steps in V.110 are to first rate-adapt the input (if required) to bring it up to the nearest sub-channel capacity, and then multiplex the sub-channels into the B channel. The input data rate is specified in the call setup message on the D channel and the network will only allow a connection if the rates are the same (38:246-251). For example, a 9.6 kbps asynchronous terminal can be rate-adapted to a 16 kbps synchronous sub-channel. This means that four such devices could access the one B channel using a TA.

V.120. The V.120 standard was originated in the US and is based on LAPD procedures with flag-stuffing used to fill the channel. V.120 is more flexible that V.110 in that it can allocate variable

bandwidth to more users on demand, although it suffers from the overhead of protocol processing of the LAPD frames. Unlike V.110, V.120 can be used on B, H0, H11 or H12 channels. V.120 manages the channel by using a 13 bit logical-link ID (LLID) and four Q.931-like messages to establish connections. If a separate D signalling channel is not available, for example in a pre-ISDN implementation, V.120 can still be implemented (provided LAPD is available) by using in-band signalling with the LLID set to zero (42:143-144).

USAF Local Information Transfer Architecture. The USAF Local Information Transfer Architecture (LITA) is currently being prototyped and evaluated at Mather AFB, CA. The LITA is based on ISDN standards and provides a base-wide digital network consisting of multiple switching nodes. The architecture recommends a minimum of two switching nodes, with more being required for larger bases. The switching nodes are connected by high speed, fiber optic links. Service nodes provide user access to the switching nodes. Individual users can be provided with BRI access, and users who spend 20 to 50 percent of the time communicating with other users in the same functional area, will be connected by LANs. LAN interconnection will be provided by ISDN up to the PRI rate (1.544 Mbps), with higher rates being provided by point-to-point fiber optic connections.

LITA Management. To provide the flexibility required to meet the varying user demands, and to meet contingencies, all service nodes will be connected to a central base network management centre. This centre will be able to manage bandwidth allocation, restore basic services in the event of network failures, and provide automatic test and full management facilities (2:pp. 3-1 to 3-14).

Scale of ISDN Implementation. The options for implementing ISDN range from replacing existing leased lines connecting distant locations to being the only telecommunications medium used for all voice, video and data requirements. The achievement of the latter option in one step would be cost prohibitive, although this might be a realistic long-term goal. Also current applications are not structured to take advantage of the integration of voice and data at the desktop (18). The proposed RAAF IS goal architecture will take a phased approach towards adopting ISDN as the primary method for providing connectivity.

Future ISDN Developments. There are two significant developments planned for ISDN that will enhance its capability. One is an extension of the V.120 concept called frame relay and the other is the introduction of broadband ISDN (B-ISDN). Frame relay and B-ISDN will be discussed and an assessment made of the likely impact on the goal architecture.

Frame Relay. Frame relay is an enhanced form of packet switching that is based on LAPD and is estimated to provide 10 times the speed of existing X.25 PSDN. X.25 provides error detection and correction on a link-by-link basis using the Layer 2 protocol and end-to-end acknowledgements and multiplexing at Layer 3. This means that the packet switching nodes must process both Layers 2 and 3. The concept of frame relay is to combine the Layer 2 and 3 functions into Layer 2 and reduce the amount of processing required at the switching nodes. The processing is reduced by only providing a core set of Layer 2 functions at the switching nodes, with any additional functions applied on an as-required basis by the end user devices, not the network. The core functions are those required to detect an error in a LAPD frame, in which case the frame is simply discarded and it is up to

the end points to recover from the error. The significant reduction in error rates in ISDN make this a reasonable approach to take. The ability to use the D signalling channel for call management also provides speed improvement by reducing the complexity of the data transfer phase. The fact that multiplexing and switching is done at Layer 2 does not preclude the use of X.25 at Layer 3. Frame relay services will be defined initially for rates up to 2 Mbps, but this could potentially reach 45 Mbps (39). The high speeds available with frame relay make it possible to send digitized voice using LAPD, although this is likely to require some form of timing adjustment at the destination to account for the variable delay of the frames (38:106). Much interest has been shown in frame relay in the US and while the CCITT standards for frame relay are being developed in the 1989-1992 working session, initial services are already being offered by some vendors (5). IBM is very interested in frame relay because of the poor match between SNA and X.25. SNA treats the X.25 Layer 3 virtual circuit as a means of providing connectivity, which is really a Layer 1 function, and then proceeds to overlay SNA Layer 2 and 3 protocols on top of this already reliable service. This takes up time and processing power (39:68). Frame relay integrates packet switching services into an ISDN in a very efficient and flexible manner and seems ideally suited to the types of services required in the RAAF IS goal architecture.

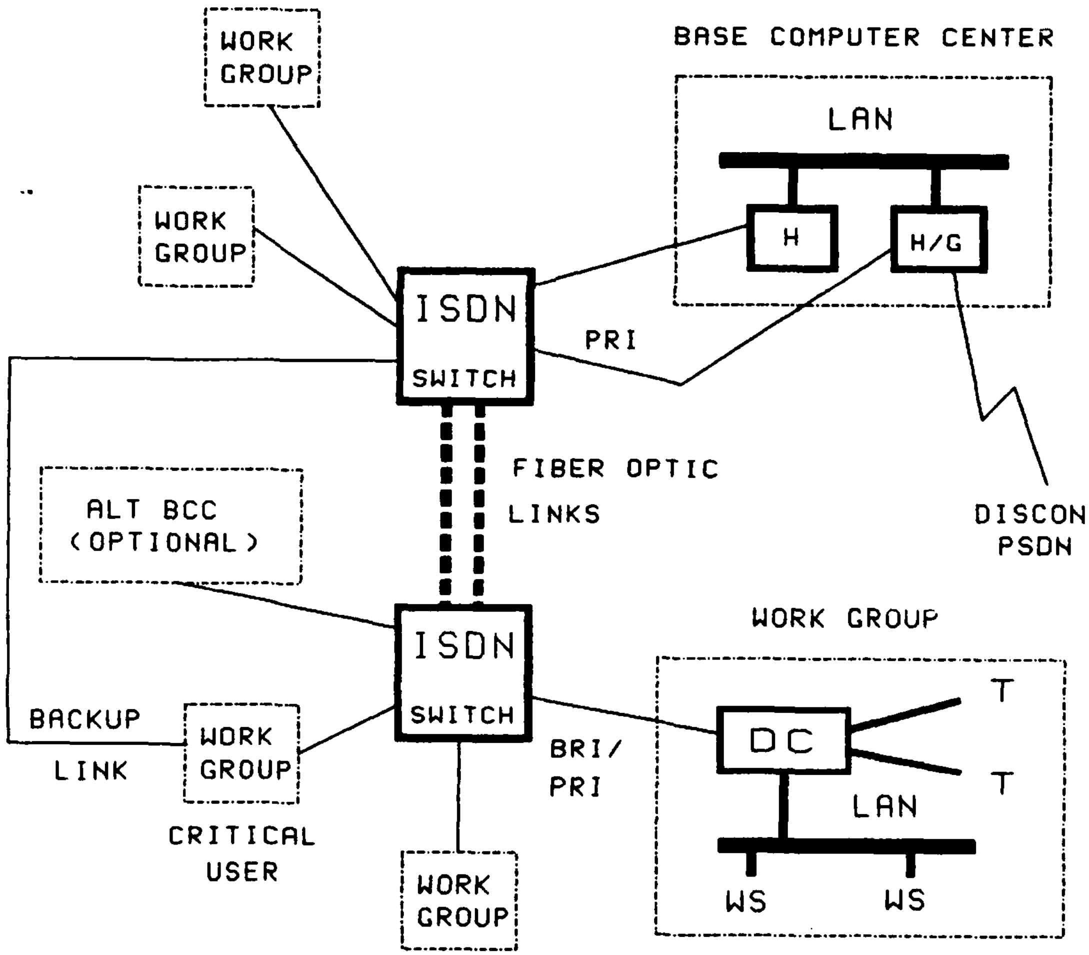
<u>B-ISDN</u>. After considering alternatives for providing the considerable higher bandwidths required for B-ISDN, in the order of 150 to 600 Mbps, the CCITT has decided on asynchronous transfer mode (ATM) as the transmission method. ATM is a packet-switched system, but instead of variable length packets or frames, a fixed length frame format is used. The size of the frame has not been decided but is

likely to be in the range of 32 to 64 bytes. This allows switching to be done at Layer 1 and thus increase performance. Higher level services can be built on top of this basic fixed size frame switching, for instance, ATM can be used to transport LAPD frames, just as LAPD frames can transport X.25 packets (41:1549-1550). One of the main motivations for B-ISDN has been for the distribution of full-bandwidth video to provide a service similar to cable TV (38:344-352). This type of service is likely to have limited application in a military environment and considering the potential of frame relay and the early stages of development of ATM, B-ISDN is not considered appropriate for the goal architecture in the foreseeable future.

Deriving the Goal Architecture

The proposed goal architecture at a base level consists of a centralized computing facility and distributed departmental or work group computers. In addition to the computers, operating systems, user terminal devices and the hardware and software to provide network connectivity are required. Figure 2 provides the layout of the goal architecture for a typical base.

Computers and Operating System. Different size computers are required to meet the various user requirements and all systems should use the multi-user Unix operating system. In the future it should be possible to specify the POSIX Unix standard in procurement activity, but at the moment specifying the AT&T Unix System V Release 3 is recommended. The reason for this is that Release 3 is the only widely available Unix standard at the moment and the fact that the RAAF already has a significant investment in System V Release 2 based systems.



KEY

T	TERMINAL	DC	DEPARTMENTAL COMPUTER
WS	WORK STATION	BRI	BASIC RATE INTERFACE
G	NETWORK GATEWAY	PRI	PRIMARY RATE INTERFACE
H	HOST COMPUTER	PSDN	PACKET SWITCHING DATA NETWORK

Figure 2. Base Level Goal Architecture

User Terminal Devices. The traditional character based terminal is still the most cost-effective way to provide computing resources to a user. Many IS applications in the RAAF are suited for, and could not justify not using, character terminals. These applications vary from transaction processing to casual OA activities. The more advanced type of applications can benefit from a windowing environment. A relatively new development called the X-Terminal is beginning to show promise in an Unix environment (3). The X-Terminal contains a processor to manage the bit-mapped display screen, keyboard and a mouse. The applications that produce the information in the windows run on other processors that are connected by some type of network. In effect, a X-Terminal is a cross between a character terminal and a full-blown X-Window workstation with a price in between, but closer to the character terminal. X-Windows workstations can be used for demanding applications that can justify the additional cost. If IBM (or compatible) PCs are required, the Lan Manager/X product provides fileserver and distributed application support from a Unix host (23:237).

Network Hardware. There are three separate components to the goal architecture network structure, the X-Terminal/workstation/PC to workgroup Unix processor, the workgroup to central base computing facility, and the inter-base network. The first of these is provided by using a IEEE 802.3/5 LAN and this component is independent of the other two. Character terminals would be directly connected to the Unix computer, although in the long term, this connection could be provided by ISDN. The third component is provided by DISCON and involves interfacing to the X.25 network. ISDN frame relay is proposed for the interconnection of the processors on a base in the goal architecture, but because frame relay is not a viable product just yet, a migration

path is required. Although the migration path will affect hardware, the decisions are based more on software aspects.

Network Software. Because the 802.3/5 LAN is as independent component, any reliable network transport service would suffice, although it would be logical to make the LAN protocols as compatible as possible with others in the network. The provision of a reliable transport service involves Layers 2 to 4, as far as software is concerned. Because Layer 4, the transport layer, is an end-to-end protocol, it is best to determine that protocol first.

Transport Protocol. OSI defines five classes of transport protocols (TP), that when matched with the service provided by Layer 3, the network layer, provide a reliable transport service to the Level 4 user. The service provided by the network layer is classified as either connection oriented (CO) or connectionless (CL). A CO service requires an exchange of messages to establish (and release) the connection and then the acknowledged transfer of data. A CL service does not require connection establishment, but mealy tries to deliver data, without acknowledgement, and with no guarantee of delivery. The Australian GOSIP requires using TP4 for CL networks and at least TP0, but preferably TP0 and TP2, for CO networks (12:2-1). TP0 and TP2 are discussed below under transport service functional requirements. X.25 is a CO service so, in order to be able to use the same TP end-to-end, intra-base communications should also be CO.

Transport Service Functional Requirements. There are six functions that must be provided by Layers 2 to 4. These functions are network addressing, multiplexing, end-to-end flow control, end-to-end acknowledgment, error detection and recovery, and segmentation of a large message into more manageable blocks and reassembly at the

destination (4:143-146). TPO is a simple protocol that provides connection management and segmentation and reassembly. All other required functions are provided by lower layers. TP2 is similar to TPO except that it can multiplex several transport sessions onto one network connection. This capability also adds the requirement to be able to do end-to-end flow control and acknowledgement. TPO and TP2 are not capable of recovering from a malfunction that causes a network reset. If this should occur then all associated transport connections would be lost.

Frame Relay Based Service. A frame relay based service can be used to provide the required level of functionality. First the Q.931 setup message contains the network address. If the full LAPD is terminated at the end user locations, then multiplexing, end-to-end flow control and acknowledgment, and error detection and recovery are provided. Segmentation and reassembly can be provided by either TPO or TP2. The gateway into the X.25 network would have to perform a protocol conversion and address translation from ISDN to PSDN addressing. The protocol conversion involves mapping the LAPD frame to the LAPB frame and Layer 3 packet and vica versa. A major objection to protocol conversion is its special-purpose nature that can get out of hand if many conversions are required, although in this case only one conversion is proposed (37:463). The alternative would be to use X.25 packet layer protocol (PLP) at Layer 3. X.25 PLP adds complexity without any real benefit. X.25 PLP has an optional D-bit procedure that can be used to provide end-to-end acknowledgment, but as the Australian GOSIP does not recommend using this feature, TP2 would have to be added to provide this acknowledgment (12:3A-4). This would mean that for a single transport connection there would be three end-to-end acknowledgments occurring at

Layers 2, 3 and 4. Figure 3 shows the goal architecture network protocols for Layers 1 to 4 for the work group and also the DISCON gateway. Other computer systems at the computer centre would have a protocol stack the same as the work group. Only ISDN user plane protocols are shown and this is one of the advantages of an ISDN where the data transfer protocols are separate from the control protocols. This allows a more efficient design for the data transfer program, by only having to process data protocol units and not data as well as control protocol units. This improves network throughput and reduces the delay on each data protocol unit.

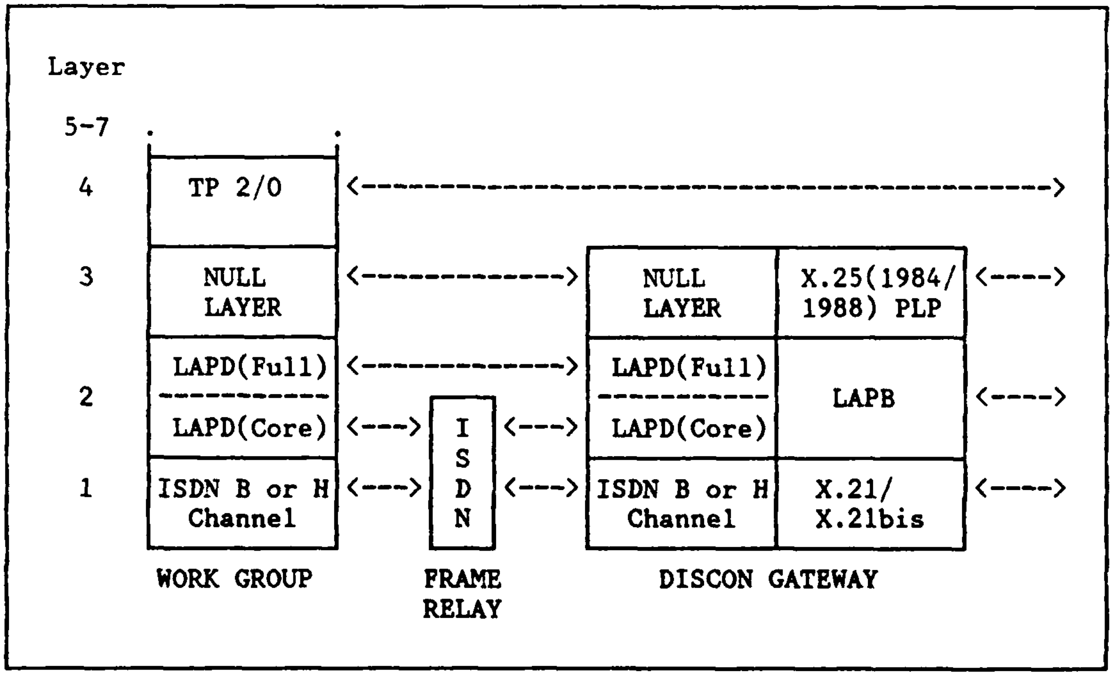


Figure 3. Goal Architecture Network Protocols (User Plane)

In addition to the ISDN user plane protocols, the standard ISDN control plane protocols are required. These protocols are depicted in Figure 4.

Layer			
3	Q.931 Signalling	<------------>	Q.931 Signalling
2	LAPD (Full)	<------------>	LAPD (Full)
1	ISDN D Channel	<------------>	ISDN D Channel

Figure 4. ISDN Signalling Protocols (Control Plane)

<u>Migration Protocols</u>. To allow a smooth introduction of OSI services and allow for the incorporation of existing systems, a migration path is proposed. The lowest common denominator is likely to be a basic X.25 service, possibly based on the 1980 standard, that does not use any transport protocol. This situation is not OSI compatible but does provide a reliable, and commonly available, transfer of data between end points implementing this raw X.25 service. If communications are required with OSI networks, then TP0 or TP2 can optionally be added. During this migration period it would be nice to be able to insulate the transport users from the underlying implementation. Fortunately, Unix System V Release 3 has such a feature. The migration protocols shows X.25 (1980), but as long as all systems are using a compatible version of X.25, internetworking should be possible. A

migration plan should be established to provide full Australian GOSIP compliance. Figure 5 shows the X.25 migration protocols.

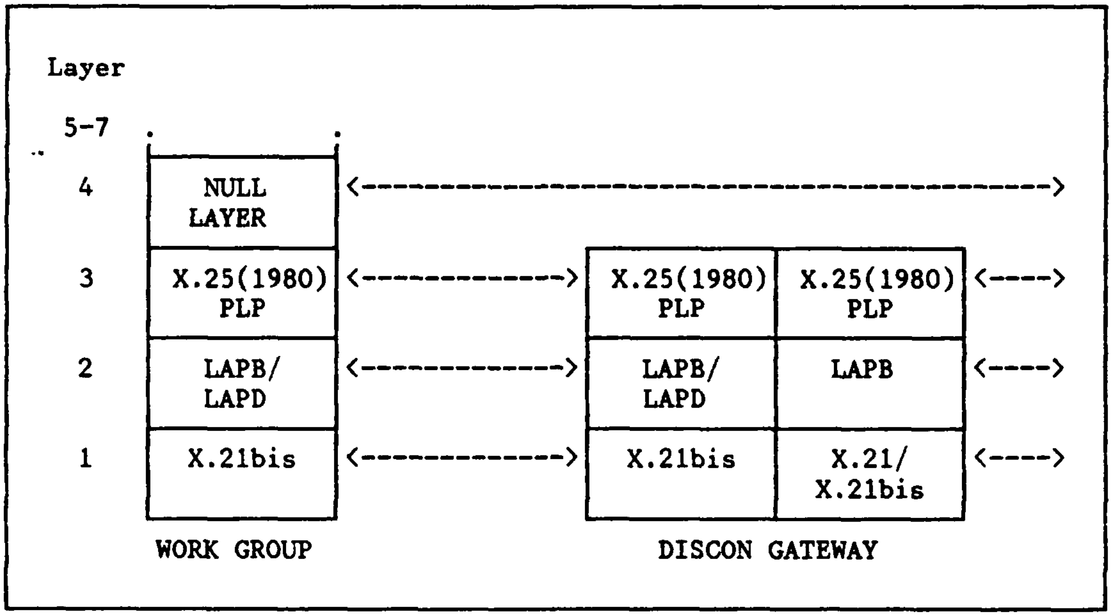


Figure 5. Migration Network Protocols

System V Transport Layer Interface. The System V Transport Layer Interface (TLI) was introduced with Release 3 to provide a protocol independent method of accessing the network services. TLI is a programmatic interface that sits on top of a transport provider, that is Layer 4. Vendors have used TLI to develop OSI applications like X.400 E-Mail, File Transfer and Access Method (FTAM) etc. TLI allows the protocol stack to be changed without having to modify application programs. This is a boom to applications developers who must support different protocols (36).

Evaluation of Goal Architecture

Estimates of the actual network load were not available for use in evaluating the proposed architecture. The SWU was devised to examine network performance under varying loads. The varying loads were used as input to the CACI COMNET II.5, Version 2.9, simulation program, an overview of which is provided at Appendix C. The aim of the simulation was to check the performance of a 64 kbps channel by varying the number of SWUs until the channel utilization reached the maximum possible value of 1.

Appendix D shows the input and output for the COMNET II.5 simulation for a network load of 20 SWUs. The load was varied from 20 to 140 SWU, in increments of 20, and a summary of the results is contained in Appendix E. The network performance can best be assessed by looking at the simulation results for the interactive database query portion of the SWU. Figure 6 shows the effect of increased network load (SWU) on the average message delay.

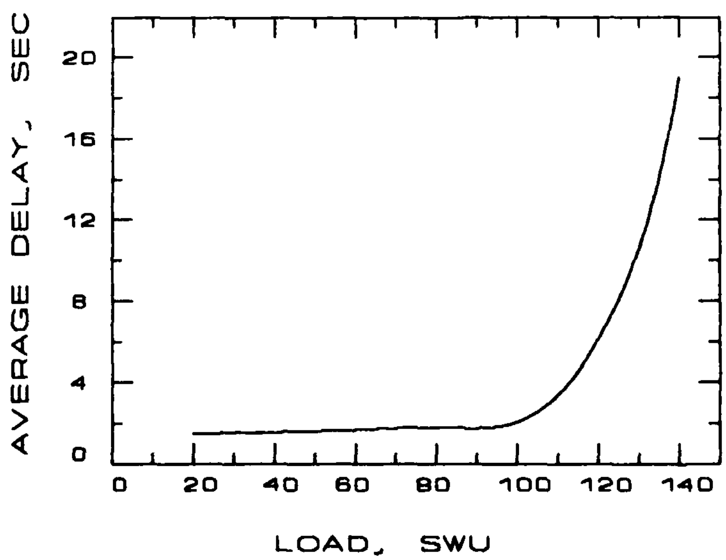


Figure 6. Database Query Performance

The database query performance shows a steadily increasing average delay with increasing load. At about 95 SWU, this trend changes and there is a large increase in delay for a correspondingly small increase in load. The path from the work group (WG) to the computer centre (CC) only reaches 0.41 utilization at 140 SWUs, where the reverse direction has reached 0.993 utilization, or just about full capacity. The data for the message from the CC to the WG shows a similar trend with a break-point at about 100 SWUs. Because of the under utilization of the WG to CC path, the delay for messages in that direction showed a gentle increase across the entire range simulated.

The database query delay time is affected by the message traffic from CC to WG, because they are both competing for the same channel. Interactive performance could be improved by using a priority scheme, where interactive sessions would have a higher priority over less critical activities, like E-Mail delivery. Another method would be to use the second 64 kbps B channel for message delivery, and only have interactive traffic in the first B channel. Of course, the higher capacity H channels could be used which would reduce the transmission time, as well as the queuing time.

The simulation of the link from the CC to a WG has shown that if a network is designed so that only necessary traffic is placed on the network, then a 64 kbps channel can handle a reasonable amount of traffic before queuing delays adversely affect performance.

V. Discussion of Findings

Assessment of Meeting RAAF IS Development Framework Requirements

The paper titled "A Development Framework for RAAF Information Systems" identified four important aspects of the IS goal architecture (33). They were, identifying a total system concept, the ability to transfer data between functional systems, the protection of classified data, and the support for deployments. An assessment of how the proposed goal architecture meets these requirements is provided below.

Unifying Total System Concept. ISDN provides the unifying total system concept by enabling all base communications requirements to be provided by the one network structure. A local base ISDN distribution system provides a flexible network that can meet all requirements for voice, video and data. The network management capability of the D channel provides the fault detection and rectification necessary to adapt to changing requirements in base communications.

Transfer of Data Between Systems. Two requirements must be met in order to exchange meaningful data between computer systems. First, common network protocols must be used to enable the reliable transfer of data, and secondly, there must be an agreed upon format for the exchanged data. The first requirement is met by using the TLI to provide a consistent interface to the users of the network transport service. This allows the protocols to migrate from a basic X.25 service to full OSI in a controlled fashion. The second requirement is more difficult to obtain, as it requires agreement from the various IS projects on data formats and the problems of data ownership must be addressed. The format problem can be simplified if all systems use the same DBMS standard, and with the strong emphasis on relational DBMS,

that means using SQL based products. Because each DBMS vendor has provided a super-set of the defined SQL standard, integration problems can be reduced by reducing the number of different DBMS products used, with the ideal being only using one of the leading DBMS vendors. In any case, a Data Administration (DA) function, which is not the same as Database Administration (DBA), should be established to define the scope and format of corporate data. In simple terms, the DA function sets the policy for the management of corporate data, and the DBAs implement that policy.

Protection of Classified Data. The protection of classified information is paramount in a military environment. The method discussed for the protection of classified data in the earlier draft paper for the development of RAAF IS, is to implement two completely separate networks, one for unclassified users, and the other for classified users. This concept has the advantage of providing guaranteed separation among different security domains, but also creates several problems. The first problem is that two independent networks have to be designed, implemented and maintained. A second problem is that this scheme presupposes that the identification of classified users can be based on the functional area concerned, and remains static over time. But, this is not generally the case because aggregated lower classified data may have a higher classification and the classification of certain data may change as the alert status of a base changes. For instance, in peace-time the quantity of fuel on a base may warrant a low classification, but during increased alert status, this type of data may become highly classified because it indicates capability to continue with flying operations.

End-to-End Encryption. To meet the security requirements, in a flexible manner, the proposed solution is to use end-to-end encryption over a switched B or H ISDN channel. This would require the acquisition, or development, of encryption devices that can encrypt the B or H data channel and leave the D signalling channel in the clear. This type of scheme requires a circuit switched connection and can not make use of a frame relay capability because the LAPD header, which is used by the switching nodes to make routing decisions, is also encrypted. Placing encryption devices at each end of the links to the switching nodes would solve the routing problem, but would introduce a security risk by mixing unclassified and classified data in the switching nodes. If encryption devices can operate above the Data Link Layer, then it should be possible to pass encrypted data through a frame relay network.

Support for Deployments. An important requirement for the goal architecture is to provide support for deployed operations, which might be at another operational RAAF base, RAAF bare-base facility, or civilian airfield. If ISDN services can be provided at these other locations, then it is a simple matter to provide a connection back to any operational base or headquarters. Again, encryption can be used to protect classified data over the public, Telecom Australia, ISDN. Telecom Australia ISDN services are currently available in the major capital cities, with additional services being made available as time and money permit. In the longer term, ISDN will be available at every location that the RAAF may be required to operate from. Another possibility, is to provide BRI service by using remote satellite equipment (22:1049).

Assessment of Meeting DESINE Goals

The goals of the DESINE contract were discussed in Chapter IV by describing the benefits of the project. The first five benefits are dependent on the particular architecture and will be discussed below.

Proven Hardware, Software and Network Architecture. Interoperability between the different functional areas is to be enhanced by using a proven hardware, software and network architecture. Assuming IBM will implement SNA protocols for the DESINE contract, there is no doubt that a proven architecture will result. But, there are two problems with this approach, both of which have been discussed previously. The first is the poor match of SNA and X.25, which is significant because X.25 is the standard being used for the DISCON packet switching service. The second, and perhaps more important, problem is the lack of a defined migration path to meet the Australian GOSIP requirements. The proposed architecture used X.25 as a migration path towards compliance with Australian GOSIP and will implement the frame relay standards when they are finalized. This architecture is capable of providing OSI X.400 E-Mail, File Transfer and Access Method (FTAM), and providing for client-server database operations using the AT&T TLI. This provides a level of interoperability that enables the movement of data and messages between different systems. This, X.25 based, migration path also allows many of the existing computers to be integrated into the architecture.

Saving in Training and Other Support Costs. The proposed architecture will eventually integrate all information transfer services on a base, and thus reduce the training and support costs involved in maintaining separate networks for voice, data and video. The use of

Unix as the only operating system will reduce the training costs required for system developers and managers.

Increased Contingency and Backup Potential. The proposed architecture contains a lot of small, microprocessor based, Unix systems. This makes it possible to store data at a remote backup site and the relatively low cost of the computer systems makes the concept of a hot backup economically feasible. This factor may be important for deployments away from the main RAAF bases.

The Contracted Availability of New Technology to Meet GOSIP. The proposed architecture provides a migration path to fully implementing Australian GOSIP standards. ISDN standards will be added to GOSIP in later versions, so full compliance using ISDN protocols, will be possible in the future.

Increased Australian/New Zealand Industry Participation. Australian and New Zealand computer vendors are more likely to be able to produce systems that are based on open systems standards, like POSIX, than proprietary systems. Local industry participation could be further enhanced by selecting computer industry standards for the microprocessor, computer bus structure etc. This would give the local vendors an opportunity to design systems that would meet the requirements of a contract like DESINE.

Assessment of Meeting User's Communications Needs

Without actual estimates of the type and volume of user network traffic it is difficult to make any positive statement about the ability of the proposed goal architecture to meet user's communications needs. Nevertheless, the simulation results do provide a good indication of the type of network load that can be supported by a 64 kbps full-duplex ISDN

B channel. If communications requirements can be met by the ISDN B channel then the provisioning of network services to users on a base is simplified because the ISDN BRI can be provided at any location that currently has a telephone. This ability to quickly relocate computer equipment is important in a military environment.

The point at which the average message delay began to increase rapidly was about 95 SWU. Analysis of the results for 80 SWU gives an indication of the performance of the link in the more stable region. At 80 SWU the average time between database queries was about 1.3 seconds. The queries were an average size of 2,970 bytes and removing the fixed one second delay before a response and the transmission time of about 0.36 seconds, leaves an average queuing delay of 0.44 seconds and a maximum queuing delay of 1.69 seconds. In a real situation a small work group is unlikely to be making queries at a continuous 1.3 second rate. At the same time the 80 SWU load generates, on average, a message of average size 5,550 bytes from the WG to CC every 2.5 seconds, and a message of similar size every 1.5 seconds from the CC to WG.

To generate a real network load that is similar to a load of 80 SWU in a normal RAAF environment would require a reasonable sized work group of very active users. Performance can be increased by reducing the number of users in the same work group or by increasing the bandwidth of the link to the CC.

Conclusions

The key to the goal architecture is providing work group computing power at the user locations. These systems should take advantage of the price/performance advantage of microprocessor based systems, and to ensure future portability and reduced maintenance costs, the Unix

operating system should be used. These work group computers are linked to a computer centre where centralized services, like DBMS and E-Mail are provided. This link will eventually be provided by the ISDN frame relay service, although initially it will be provided by X.25.

This research has identified an architecture that meets the specific operational requirements of the RAAF. With correct distribution of processing power the 64 kbps ISDN B channel is capable of supporting most user requirements for low speed data. The concept of ISDN is to eventually integrate all voice, video and data services into a flexible network that is capable of rapid reconfiguration to meet user demands. ISDN should be considered as the basis of the RAAF IS goal architecture.

Appendix A: Network Primer

This appendix gives an overview of some networking concepts that should allow a non-technical reader to understand the network concepts discussed in this research. First, some general network terms will be described, then the alternative methods of moving, or switching data through a network. A short discussion of the International Standards Organization/ Open Systems Interconnection (ISO/OSI) model will allow the CCITT X.25 network standard to be introduced.

Types of Networks. A computer is an interconnected collection of autonomous computers, often referred to as nodes on the network. The goals of a network are resource sharing, both equipment and data, improved reliability by having alternative sources, and cost saving because of the better price/performance ratio of small computers as compared to large ones. Computers in the same geographic location, generally within a few miles, can be interconnected with Local Area Networks (LAN). Connectivity between widely dispersed computers or LANs is provided by Wide Area Networks (WAN). WANs typically operate at speeds much less than LANs (40:2-4).

Network Data Switching. There are three basic ways that data can be transported through a network. They are by, circuit switching, message switching, or packet switching. In circuit switching, a dedicated physical circuit is made between the two parties wishing to communicate and data is passed in an agreed format. Store-and-forward message switching is another method of transferring data, by the use of intermediate nodes. A connection is made between two adjacent nodes only for the length of time necessary to transfer the message. The network then moves, or switches, the message to the destination in a

series of hops. A more refined form of message switching is packet switching. In packet switching data is segmented into small packets and the packets are switched through the network. Packet switching networks can be used to implement a message switching capability (38:65-78).

Open Systems Interconnection Model. ISO developed a seven layer OSI network model that clearly defined the functions of each layer in the network. Interfaces between the layers were also defined so as to make the implementation of each layer as independent as possible from the other layers. Figure 7 shows the seven layers divided into two sections. The first section, consisting of Layers 1 to 3, provides the network service to the transport layer. The second section, Layers 4 to 7, contains those network functions that use the transport service.

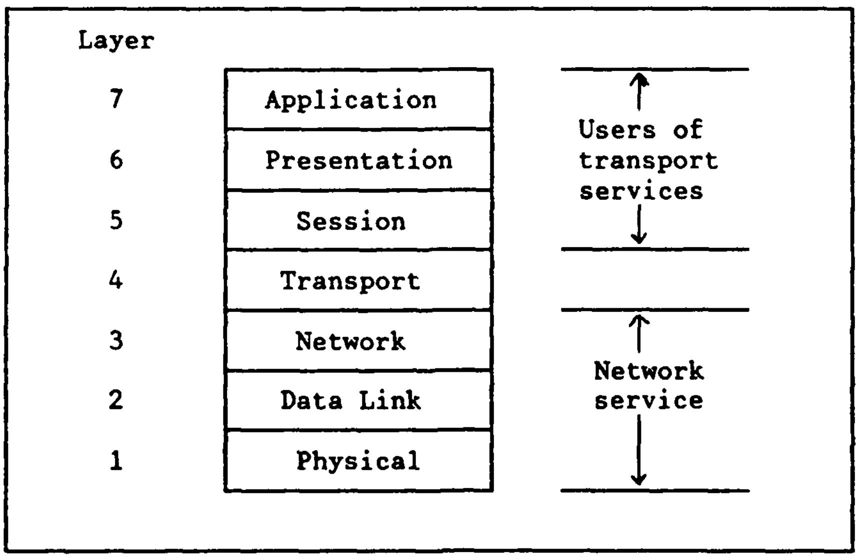


Figure 7. OSI Model (38:389)

Collectively, Layers 1 to 4 are concerned with the reliable transfer of data through the network, and are of concern to network designers, and thus will be discussed further.

Physical Layer. The physical layer is concerned with the rules that govern the transfer of bits between devices. This includes the mechanical, electrical, functional and procedural characteristics of the interface (38:385).

Data Link Layer. The data link layer forces some form of order on the bit stream, with the aim of providing an error-free link between two adjacent nodes (38:386).

Network Layer. The network layer shields the transport layer from the actual transmission and switching technologies. This layer is also responsible for establishing, maintaining, and terminating connections across multiple data links (38:386).

Transport Layer. The function of the transport layer is to ensure that data units are delivered error-free, in sequence, and without loss or duplication. The amount of work done at this layer depends on the reliability of the service provided by the network layer (38:387).

X.25 Packet Switching Standard. X.25 is a very widely used packet switching standard that was introduced in 1976, and has been updated at four yearly intervals. X.25 specifies the network access from a host to a packet switched data network (PSDN) by defining the protocols for Layers 1 to 3. Layer 1 specifies X.21 or the more commonly availabie X.21 bis. The Layer 2 protocol is Link Access Protocol B (LAPB). Layer 3 is where all the functionality lies, with the X.25 Packet Layer Protocol (PLP). The X.25 PLP can provide up to 4096 virtual circuits, possibly to different destinations, at the one network connection. X.25

(1984) PLP has been specified as the connection-oriented (CO) network protocol for OSI networks. CO services are provided by first establishing a connection with the destination, then transferring the required data, and finally releasing the connection. During the data transfer phase, data packets contain a virtual circuit number to identify the connection. CO networks are contrasted with datagram or connectionless (CL) networks where data packets are self contained, that is contain the full destination and source address etc, and thus connection establishment is not required (38:89-101).

Appendix B: Definition of Standard Work Unit

The standard work unit (SWU) is defined as a specified amount of network traffic that is conducted within a five minute period. The interchange involves three separate activities between two nodes on the network. These nodes have been labled CC for computer centre and WG for workgroup. The details for the various transaction types are given in Table 1.

Table 1. Standard Work Unit

Transaction Type	Source	Dest	Details
Database Virtual Call	WG	CC	Each call consists of 3 to 4 queries, 20 to 30 seconds apart. Query size is 150 to 400 bytes and produces a reply of 1,000 to 4,000 bytes after a one second delay.
E-Mail or file transfer	CC	WG	Transfer two files or E-Mail messages of 1,000 to 10,000 bytes each.
E-Mail or file transfer	WG	CC	Transfer a file or E-Mail message of 1,000 to 10,000 bytes.

The distributions for message, query and response size is uniform. The inter-arrival distribution for the transaction types is gamma. To vary the network traffic, the transaction inter-arrival time was varied. The message, response, and file sizes were selected to be indicitive of a typical situation, and do not represent any defined requirements. A one second delay between a database query and the corresponding reply

was selected to show some load on the database back-end. This time does not indicate any real specification. In reality this parameter is very dependent on the type of hardware, DBMS software and computer loading.

The SWU load was varied from 20 to 140 in increments of 20. The various inter-arrival times are presented in Table 2.

Table 2. Transaction Inter-arrival Time

SWU	Database Virtual Call/ E-Mail WG - CC (seconds)	E-Mail CC - WG (seconds)
1	300.0	150.0
20	15.0	7.5
40	7.5	3.75
60	5.0	2.5
80	3.75	1.875
100	3.0	1.5
120	2.5	1.25
140	2.14	1.071

Appendix C: Overview of COMNET II.5

COMNET II.5 is a telecommunications network analysis program that operates on IBM PC-XT, AT, or PS/2 PCs, SUN-3/4 workstations, and DEC VAX/VMS systems, with implementations being planned for other computers. The program was developed by CACI Products Company of 3344 North Torrey Pines Court, La Jolla, CA 92037 (Phone: (619) 457-9681). It uses discrete event simulation to model the operation of a network and provide performance measurements from a description of the network and its routing algorithms. COMNET II.5 can be used to simulate any WAN that uses circuit switching, message switching, or packet switching. Packet switching can be based on either virtual circuits or datagrams. No programming is required to use COMNET II.5 and all parameters are provided using data entry screens. The IBM PC-AT Version 2.9 of COMNET II.5 was used for the simulation.

Network Topology

The network topology consists of a series of nodes that represent sources and destinations for network traffic. Links are defined that connect any two nodes. Input parameters are required that define the performance characteristics of the nodes, such as, number of packet switching processors per node and the packet switching time per processor. Link failure can be simulated to determine the effects of network performance.

Network Traffic

COMNET II.5 can simulate circuit switched calls, data messages (circuit switched or packet switched) and virtual circuit calls. Each traffic category is defined by the source and destination nodes and a class of service. Circuit switched calls have interarrival time distribution, call holding time distribution parameters, and an indication of whether calls can be queued. Data messages require a message size distribution parameter. Virtual circuit calls require additional parameters, for example, the messages-per-call distribution, the message interarrival time distribution, the message size distribution, the probability of getting a response from a message, the response message size, and the delay before transmission of the response. COMNET II.5 provides many distributions and random number streams to cover almost any required situation.

Appendix D. Simulation Input and Output - Load 20 SWU

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64 kbps full-duplex Load 20 SWU

NODE ATTRIBUTES

NODE ID CODE	CC	WG
NODE NAME	Computer Cent.	Work Group
DISPLAY COLUMN	0	0
DISPLAY ROW	0	0
SWITCHING TIMES (MS)		
CALL SETUP TIME	0.	0.
MESSAGE SETUP TIME	0.	0.
V CKT SETUP PKT TIME	10.00	10.00
PKT PROCESSING TIME	1.00	1.00
PKT PROC TM PER KBYTE	0.	0.
BUFFER SIZE (BYTES)	65535	65535
MSG-CUTOFF (BYTES)	buff. size	buff. size
PKT SWITCH PROCESSORS	1	1
PACKETIZING DELAY (MS)	1.00	1.00

64 kbps full-duplex Load 20 SWU

CIRCUIT GROUP ATTRIBUTES

CIRCUIT GROUP ID CODE	CC-WG	WG-CC
SOURCE NODE ID CODE	CC	WG
ADJACENT NODE ID CODE	WG	CC
NUMBER OF CIRCUITS	1	1
DISPLAY?	no	no
TWO-WAY OPERATION?	no	no
CIRCUIT SPEED (KBPS)	64.00	64.00
CIRCUIT-SWITCHING ATTRIBUTES		
BANDWIDTH ALLOCATION?	no	no
CALL SIG. TIME (MS)	0.	0.
ACCESS LEVEL	1	1
TANDEM CALLS?	no	no
QUEUEING ALLOWED?	no	no
CALL QUEUE LIMIT	none	none
MSG SIG. TIME (MS)	0.	0.
PACKET-SWITCHING ATTRIBUTES		
FDX REVERSE CKT GROUP	WG-CC	CC-WG
PROPAGA. DELAY (MS)	0.	0.
MAX BUFF. USE (BYT	no limit	no limit
BUFF. RESERVE (BYTES)	0	0
MAX VIRT. CKTS	no limit	no limit
FAILURE ATTRIBUTES		
TIME-TO-FAIL DISTR	unspecified	unspecified
MTTF (HOURS)	0.	0.
TIME-TO-REPAIR DISTR	unspecified	unspecified
MTTR (HOURS)	0.	0.

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64 kbps full-duplex Load 20 SWU

CLASS-OF-SERVICE ATTRIBUTES

CLASS-OF-SERVICE ID CODE	DB	MSG
PRIORITY	1	1
CIRCUIT-SWITCHING ATTRIBUTES		
CALL RETRY DISTRIB.	unspecified	unspecified
AVG RETRY TIME (MIN)	0.	0.
BANDWIDTH REQT (KBPS)	0.	0.

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64 kbps full-duplex Load 20 SWU

VIRTUAL CALL ATTRIBUTES

ORIGIN NODE ID CODE	CC	WG	WG
DEST. NODE ID CODE	WG	CC	CC
CLASS-OF-SVC ID CODE	MSG	DB	MSG
WINDOW SIZE	0	1	0
RESPONSE PROBABILITY	0.	1.00	0.
RESPONSE DELAY (SEC)	0.	1.00	0.
CALL INTERARRIVAL TIME (SEC)			
PROB. DISTRIBUTION	gamma	gamma	gamma
PARAMETER 1	7.50	15.00	15.00
PARAMETER 2	1.50	1.50	1.50
PARAMETER 3	0.	0.	0.
PARAMETER 4	0.	0.	0.
STREAM	1	1	1
NO. OF MSGS PER CALL			
PROB. DISTRIBUTION	constant	uniform	constant
PARAMETER 1	1.00	3.00	1.00
PARAMETER 2	0.	4.00	0.
STREAM	0	1	0
MSG INTERARRIVAL TIME (SEC)			
PROB. DISTRIBUTION	uniform	uniform	uniform
PARAMETER 1	1.00	20.00	1.00
PARAMETER 2	2.00	30.00	2.00
PARAMETER 3	0.	0.	0.
PARAMETER 4	0.	0.	0.
STREAM	1	1	1
MSG SIZE (BYTES)			
PROB. DISTRIBUTION	uniform	uniform	uniform
PARAMETER 1	1000.00	150.00	1000.00
PARAMETER 2	10000.00	400.00	10000.00
STREAM	2	2	2
RESPONSE SIZE (BYTES)			
PROB. DISTRIBUTION	unspecified	uniform	unspecified
PARAMETER 1	0.	1000.00	0.
PARAMETER 2	0.	4000.00	0.
STREAM	0	1	0

64 kbps full-duplex Load 20 SWU

CIRCUIT-SWITCHING OPERATION

Call Preemption Enabled?	No
Call Routing Strategy	Undefined

PACKET-SWITCHING OPERATION

Message Traffic Switching	Packet-Switched	
Information Bytes per Packet	251	
Overhead Bytes per Packet	6	
Acknowledgement Packet Size	6	
Link Level Bytes Per Packet	8	
Control Packet Priority	0	(0 defaults to highest priority)
Acknowledge End of Message	No	
Retransmit Interval	500	millisec
Routing Update Interval	10000	millisec
Packet Routing Strategy	User-Defined Node-by-Node Routing Tables	
Alternate Routing Rule	Maximum Excess Transmission Capacity	
Traffic Measure Type	Undefined	
Max Distance Change Threshold	0	millisec
Distance Change Threshold Reduction	0	millisec
Max Flooded Packet Life	0.	sec
Virtual Call Retry Interval	60.00	sec
Max Retransmit Attempts	0	
Call Request Packet Size (Bytes)	0	
Call Connect Packet Size (Bytes)	0	
Virtual Call Flow Control Strategy	Sliding Window	

64 kbps full-duplex Load 20 SWU

NODE-BY-NODE ROUTING TABLES FOR PACKETS

WITH CLASS OF SERVICE DB

CIRCUIT GROUP ID CODES FOR ROUTING CHOICES

ROUTING NODE: CC
  DEST. NODE: WG   CC-WG
ROUTING NODE: WG
  DEST. NODE: CC   WG-CC

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64 kbps full-duplex Load 20 SWU

NODE-BY-NODE ROUTING TABLES FOR PACKETS

WITH CLASS OF SERVICE MSG

CIRCUIT GROUP ID CODES FOR ROUTING CHOICES

```
ROUTING NODE: CC
  DEST. NODE: WG        CC-WG
ROUTING NODE: WG
  DEST. NODE: CC        WG-CC
```

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64 kbps full-duplex Load 20 SWU

CIRCUIT GROUP PERFORMANCE
FOR
PACKET-SWITCHED TRAFFIC
FROM 0. TO 5. MINUTES

CIRCUIT GROUP ID CODE	CC-WG	WG-CC
SOURCE NODE	Computer Cent.	Work Group
ADJACENT NODE	Work Group	Computer Cent.
CALL SETUP DIRECTION	1	1
NUMBER OF CIRCUITS	1	1
BUSY CIRCUITS (ALL TRAFFIC)		
AVERAGE	.15	.08
STANDARD DEVIATION	.35	.27
MAXIMUM	1.00	1.00
CIRCUIT GROUP UTIL %	14.69	7.88
NO. OF PACKETS TRANSMITTED		
FROM SOURCE NODE	2092	2092
BUFFER USE (BYTES)		
AVERAGE	79.02	36.63
STANDARD DEVIATION	186.81	122.80
MAXIMUM	1220.00	824.00
PACKET QUEUE TIME (MS)		
AVERAGE	3.05	.14
STANDARD DEVIATION	8.96	1.88
MAXIMUM	60.50	32.12

64 kbps full-duplex Load 20 SWU

PACKET SWITCHING
NODE UTILIZATION STATISTICS
FROM 0. TO 5. MINUTES

NODE	Computer Cent.	Work Group
BUFFER USE (BYTES)		
AVERAGE	79.02	36.63
STANDARD DEVIATION	186.81	122.80
MAXIMUM	1220.00	824.00
PACKETS PROCESSED	4184	4184
PACKETS BLOCKED	0	0
PKT SWITCH WAIT TIME (MS)		
AVERAGE	.01	.01
STANDARD DEVIATION	.25	.18
MAXIMUM	7.43	7.25
PROCESSOR UTILIZATION		
PROCESSORS PER NODE	1	1
AVG BUSY PROCESSORS	.02	.02
UTILIZATION %	1.62	1.62

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64 kbps full-duplex Load 20 SWU

MESSAGE DELAY STATISTICS
FROM 0. TO 5.0 MINUTES

ORIGIN	DEST.	COS	MSGS BLOCKED	MSGS SENT AND RECEIVED	AVG SIZE IN BYTES	MESSAGE DELAY (SECONDS) AVERAGE	STD DEV	MAXIMUM	TOTAL PACKETS	AVG DELAY (MS)
CC	WG	MSG	0	33	5475.9	.93	.47	2.00	735	578
WG	CC	DB	0	58	2737.9	1.49	.20	2.11	693	224
WG	CC	MSG	0	25	5775.8	.90	.40	1.47	588	534
NETWORK TOTALS			0	116	4171.6	1.20	.44	2.11	2016	443

NETWORK THROUGHPUT: 12.9 KILOBITS PER SECOND

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64 kbps full-duplex Load 20 SWU

VIRTUAL CIRCUIT CALL STATISTICS
FROM 0. TO 5.0 MINUTES
(ALL TIMES IN SECONDS)

CALL ORIGIN	CALL DEST.	COS	CALLS TRIED	CALLS BLOCKED	CALLS RE-ROUTED	SETUP DELAY AVG	STD	MAX	CALLS ENDED	AVG CALL LENGTH
CC	WG	MSG	33	0	0	.03	.00	.04	33	1
WG	CC	DB	18	0	0	.03	.01	.05	15	63
WG	CC	MSG	25	0	0	.02	.00	.03	25	1

Appendix E. Simulation Results - Summary

The results of the COMNET II.5 simulation for a 64 kbps full-duplex circuit from the Work Group (WG) to the Computer Centre (CC), for various load factors, are shown in Table 3.

Table 3. Summary of Simulation Results

Load (SWU)	Link Utilization CC-WG	Link Utilization WG-CC	Traffic Type	Message Delay (sec) Average	Message Delay (sec) Maximum
			Msg CC-WG	0.93	2.00
20	0.147	0.788	DB Query	1.49	2.11
			Msg WG-CC	0.90	1.47
			Msg CC-WG	0.97	2.47
40	0.294	0.142	DB Query	1.56	2.50
			Msg WG-CC	0.92	1.89
			Msg CC-WG	1.20	4.53
60	0.446	0.218	DB Query	1.67	2.91
			Msg WG-CC	1.05	2.51
			Msg CC-WG	1.43	4.75
80	0.608	0.296	DB Query	1.80	3.05
			Msg WG-CC	1.18	2.68
			Msg CC-WG	2.01	6.75
100	0.767	0.347	DB Query	2.06	4.53
			Msg WG-CC	1.23	3.17
			Msg CC-WG	8.58	43.08
120	0.912	0.417	DB Query	6.11	19.41
			Msg WG-CC	1.51	4.97
			Msg CC-WG	25.41	95.71
140	0.993	0.410	DB Query	18.97	70.08
			Msg WG-CC	1.60	3.71

Notes:

1. Message delay includes queuing and transmission time. The database query also includes a one second delay before the response is actioned.

2. The DB Query is from WG to CC, but the reply message, which is larger than the query message, is from CC to WG.

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GIR/ENG/89D-1	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION School of Systems and Logistics 6b. OFFICE SYMBOL (If applicable) AFIT/LSY	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Air Force Institute of Technology Wright-Patterson AFB OH 45433-6583	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
USING INTEGRATED SERVICES DIGITAL NETWORK TECHNOLOGY AS THE BASIS FOR THE ROYAL AUSTRALIAN AIR FORCE INFORMATION SYSTEMS GOAL ARCHITECTURE

12. PERSONAL AUTHOR(S)
Richard M. Halley, B.App.Sc., Wing Commander, RAAF

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
MS Thesis	FROM ____ TO ____	1989 December	83

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP
12	07	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Communications Networks ISDN Frame Relay Campus Networks Network Simulation

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Thesis Advisor: Bruce L. George

Assistant Professor

Electrical Engineering Department

Approved for public release: IAW AFR 190-1.

Larry W. Emmelhainz

LARRY W. EMMELHAINZ, Lt Col, USAF 12 Jan 90
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20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Bruce L. George, Assist. Professor	22b. TELEPHONE (Include Area Code) (513) 255-3576 22c. OFFICE SYMBOL AFIT/ENG

DD Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

The purpose of this study was to define an information systems goal architecture for the Royal Australian Air Force that uses Integrated Services Digital Network (ISDN) as the basic network structure. To do this required gathering information from previous studies on architecture requirements and present related projects. Important requirements were identified as the ability to exchange data between the various systems, the requirement to protect classified data and the requirement to support deployed RAAF operations.

An important Australian Defence project is the Defence EDP Systems Integrated Network Environment (DESINE) that is intended to achieve interoperability among the various information systems. DESINE details are not firm, but early indications are that proprietary IBM network protocols will be used with a strong emphasis on mainframe computing. This concept is contrary to the current industry trends where the use of smaller microcomputer based systems that use open systems architectures is advocated. The architecture presented in this report is offered as an alternative to DESINE.

Analysis of the options for using ISDN technology indicated that the concept of frame relay is ideally suited to the RAAF requirements. Frame relay is a form of packet switching, within an ISDN, where high throughput and low delay are achieved by reducing the processing required per packet. A migration path using conventional X.25 packet switching is proposed.

The proposed architecture distributes processing power to user locations to reduce the network traffic. This setup was simulated using the CACI COMNET II.5 program and used a surrogate load measure based on a standard work unit. This was necessary because of the unavailability of projected network load data. The results indicated that with distributed processing ISDN can meet all the requirements of the RAAF goal architecture.